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Influence of slurry and mineral fertiliser application technique on N_2O and CH_4 fluxes from a barley field

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Summary
The effect of different fertilizer application techniques on nitrous oxide (N_2O) and methane (CH_4) emissions were investigated in a field experiment. Gas fluxes were measured during a five months period in 2001 from a barley field located in Vihti, southern Finland. The effects of different fertilizer application techniques on crop yield and quality were also investigated. According to the results, slurry injection produced the most N_2O during the measurement period. Placement of mineral fertilizer produced least N_2O. Methane fluxes were close to zero and there were no statistically significant differences between the treatments. Although slurry injection is a good fertilizer application method for producing good quality crop with high yield and minimal ammonia emissions, according to this experiment, it may increase direct N_2O emissions. There is a need to develop slurry injection technique but national greenhouse gas inventory as well to include application techniques and different fertilizers.

Introduction
N_2O and CH_4 are greenhouse gases emitted from agricultural sources (Houghton et al. 2001; Bouwman 1996) and fertilizer application techniques are known to affect these emissions (Ferm et al. 1999; Flessa & Beese 2000). Currently no data has been published about the effects of different fertilizer application techniques on N_2O and CH_4 emissions from agricultural soils in Finland. Placing slurry and fertilizer in one band at sowing is one option to improve the recovery of nutrients by the plants and to minimize ammonia emissions. However, high content of soluble nitrogen and carbon may increase N_2O emissions from the band. In this field experiment, these effects were monitored during a five months period. Effects of fertilizer application techniques on crop yield and quality were also investigated.

Materials and methods
The experiment was a randomized blocks design with 12 plots, 4 treatments and 3 replicates established in Vihti, southern Finland in 2001. The field was ploughed in the autumn and in the spring before the final cultivation the field was levelled. On the 10th of May the field was cultivated to the seeding depth with a rotary tiller. Fertilizer applications were performed thereafter as described in Table 1 by using a combination of tanker and drill (Figure 1) for all the treatments.

Table 1. The amount of nitrogen applied and application technique used in the experiment

Treatment	Technique used	Slurry N (kg ha^{-1})	Mineral fertiliser N (kg ha^{-1})
S_{inj}+ F	Slurry (14.3 t ha^{-1}) injection (8 - 10 cm) and placement of mineral fertiliser in combination with sowing	79 (60[a])	50
S_{inc} + F	Incorporation of slurry (14.3 t ha^{-1}) 1 hour after band spreading followed by combine placement of mineral fertiliser and sowing	79 (60[a])	50
S_{inj}	Slurry (28.6 t ha^{-1}) injection in combination with sowing	157 (120[a])	
F_{plac}	Placement of mineral fertiliser in combination with sowing	-	100

[a] soluble N

Figure 1. Tanker and drill combination used to apply slurry, mineral fertilizer and seeds.

Gas fluxes were measured for five months after fertilization with a closed chamber method by using rectangular aluminum chambers (60 cm by 60 cm). Gas samples (20 ml) were taken from the top of the chamber by using syringe, transferred immediately to pre-evacuated glass vials and analysed with a gas chromatograph. The method has been described in details by Regina et al. (2004). The effects of different treatments on crop yield and quality are reported by Kapuinen & Tyynelä (2002).

Results and discussion

During the five-months-period slurry injection (S_{inj}) produced the most N_2O, the cumulative flux being 1100±169 g ha^{-1} (Figure 2). The second largest flux of N_2O (660±70 g ha^{-1}) was produced by slurry injection followed by placement of mineral fertilizer in combination with sowing (S_{inj}+ F). However, the differences between the treatments were not statistically significant. When slurry was incorporated one hour after band spreading followed by combine placement of mineral fertilizer and sowing (S_{inc}+F), cumulative N_2O flux was 400±37 g ha^{-1}. Placement of sole mineral fertilizer in combination with sowing (F_{plac}) resulted in a flux of 290±27 g ha^{-1}, which was not statistically different from treatment S_{inc}+F. However, treatments S_{inc}+F and F_{plac} differed significantly from treatments S_{inj} and S_{inj}+ F.

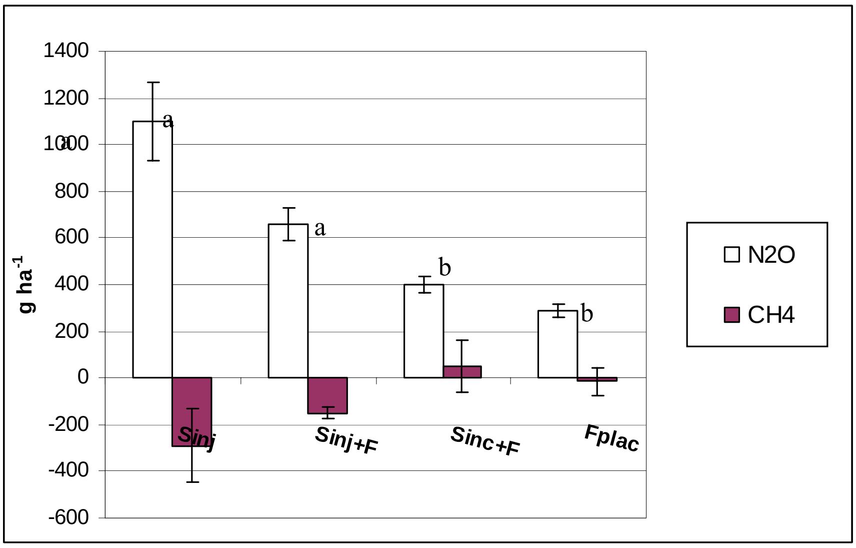

Figure 2. Cumulative N_2O and CH_4 emissions (± SE) during a five-month-period in different treatments. Different letters indicate statistical differences ($P<0.05$) between the treatments (calculated from the mean fluxes).

According to the results, slurry and mineral fertilizer application techniques seem to have an effect on the gaseous losses of nitrogen as N_2O, which is not included in the IPCC guidelines for compiling national greenhouse gas inventories (Penman et al. 2000). In this experiment, injection of sole slurry or injection of slurry followed by placement of mineral fertilizer in combination with sowing produced the most N_2O. Slurry incorporation one hour after band spreading followed by placement of mineral fertilizer in combination with sowing, and placement of sole mineral fertilizer produced the lowest fluxes. Application of slurry on surface followed by incorporation produced an emission not significantly greater than that of placement of mineral fertilizer. Slurry injection increases soil moisture content in the location favourable for denitrifying microbes whereas mineral fertilizer application does not increase soil moisture which could be the reason for the lowest N_2O emissions from placed mineral fertilizer. When slurry is spread on the surface and incorporated the moisture content does not raise over the critical level at any place, which could explain the emissions not greater than those of placed mineral fertilizer. Band spreading may have increased N volatilization directly as NH_3 thus lowering direct N_2O emissions from this treatment. NH_3 emissions and dislocation thereafter increases the indirect N_2O emissions. An application of slurry on surface followed by a rapid incorporation could result the lowest total N_2O emissions if the nitrogen is used by the plants during the season. However, in Finland, there is typically very little rain in late May and June and the nitrogen incorporated to a dry top soil layer might never be used by barley which does not take significantly nutrients after the end of June. The remaining nitrogen will potentially cause direct N_2O emissions when the rain wets the soil later or be leached in the autumn to the watercourse where it causes indirect N_2O emissions. Therefore the injection technique should be developed in a way which allows injection without increasing the moisture content locally over the critical level. A winged tine injecting slurry evenly on the seeding bed could be the solution.

Cumulative CH_4 fluxes ranged from -290 g ha^{-1} to 50 g ha^{-1} and no significant differences were noticed between the treatments. Application technique may also affect soil CH_4 oxidation capacity. In this experiment small differences between the treatments were noticed but they were not statistically different. Total emissions as affected by the application technique produced the following order $S_{inj}>S_{inj}+F>S_{inc}+F>F_{plac}$ when expressed as CO_2

equivalents. When fertilizer application techniques are developed, it would be an advantage if fertilizer nitrogen is well available for plants with minimum gaseous losses to the atmosphere. It would also be an advantage if the technique would not disturb the methane oxidation capacity of soils.

Conclusion

There is a need to develop slurry injection technique and national greenhouse gas inventory as well to include the effects of application techniques and different fertilizers.

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